Prepared For:
Kerr-McGee Chemical L.L.C.

Dye Injection Study of the Las Vegas Wash, Nevada

Prepared By:

ENSR INTERNATIONAL

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1.0 INTRODUCTION

1.1 Purpose of the Investigation

Kerr-McGee Chemical LLC (Kerr-McGee) in Henderson, NV is permitted to discharge up to 1.4 mgd of water from its treatment system to the Las Vegas Wash under NPDES permit No. NV0023060. In that permit, which was issued by Nevada Division of Environmental Protection (NDEP), Kerr-McGee was granted a mixing zone to address certain parameters in the discharge. A condition of the permit requires Kerr-McGee to conduct a tracer study to better define the mixing zone and to locate where the discharge fully mixes with flow in the Las Vegas Wash. Kerr-McGee submitted a workplan for the study[1] which was approved by the NDEP. This report presents the findings of the tracer dye study that ENSR, on behalf of Kerr-McGee, conducted during the week of October 22, 2001.

1.2 Synopsis of Investigation

Treated water from Kerr-McGee's facility discharges to a small streambed that flows into a rock-lined channel. In addition to receiving discharge from the Kerr-McGee facility, this rock-lined channel transports flow from upstream dischargers into the Las Vegas Wash. Kerr-McGee's discharge enters the rock-lined channel approximately 300 feet upstream of its discharge to the Las Vegas Wash. Fluorescent dye was used to characterize the downstream mixing of the Kerr-McGee discharge water with the ambient waters of the Las Vegas Wash (Figures 1, Figure 2). A continuous stream of dye was injected into the Kerr-McGee effluent at the point where it enters the rock-lined channel and therefore upstream of the Las Vegas Wash. The duration of the dye injection was sufficient to allow the dye to mix both laterally and vertically in the Las Vegas Wash downstream of the expected longitudinal mixing length. Once distribution of dye in the stream reached a steady state, fluorescence was measured at a series of transects downstream of the Kerr-McGee discharge. Measurements were made laterally and at mid-depth in the water column to indicate the distribution of dye in the receiving water. The most downstream transect was situated far enough away from the discharge so that the dye was completely mixed. While the location of complete mixing was not initially known, a conservative estimate was made based on the flow characteristics in the wash. Transects between the discharge and the furthest downstream transect were located to effectively characterize the mixing of the discharge plume in the Las Vegas Wash as the plume disperses downstream. In addition to the fluorescence measurements,

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[1] ENSR, 2000. Work Plan for a Dye Injection Study of the Las Vegas Wash, Nevada. Prepared for Kerr-McGee Chemical Corporation, L.L.C. Document No. 4020-011-100.

streamflow was measured at two locations including the most downstream transect and the transect just downstream of where the discharge water from Kerr-McGee enters the Las Vegas Wash.

By carefully delineating the dye plume using the fluorometric method, a longitudinal picture of the steady-state plume was developed. The mixing characteristics of the plume were identified and a clear understanding of the longitudinal distance to complete mixing was determined. The dimensions and other characteristics of the mixing zone are presented in this report.

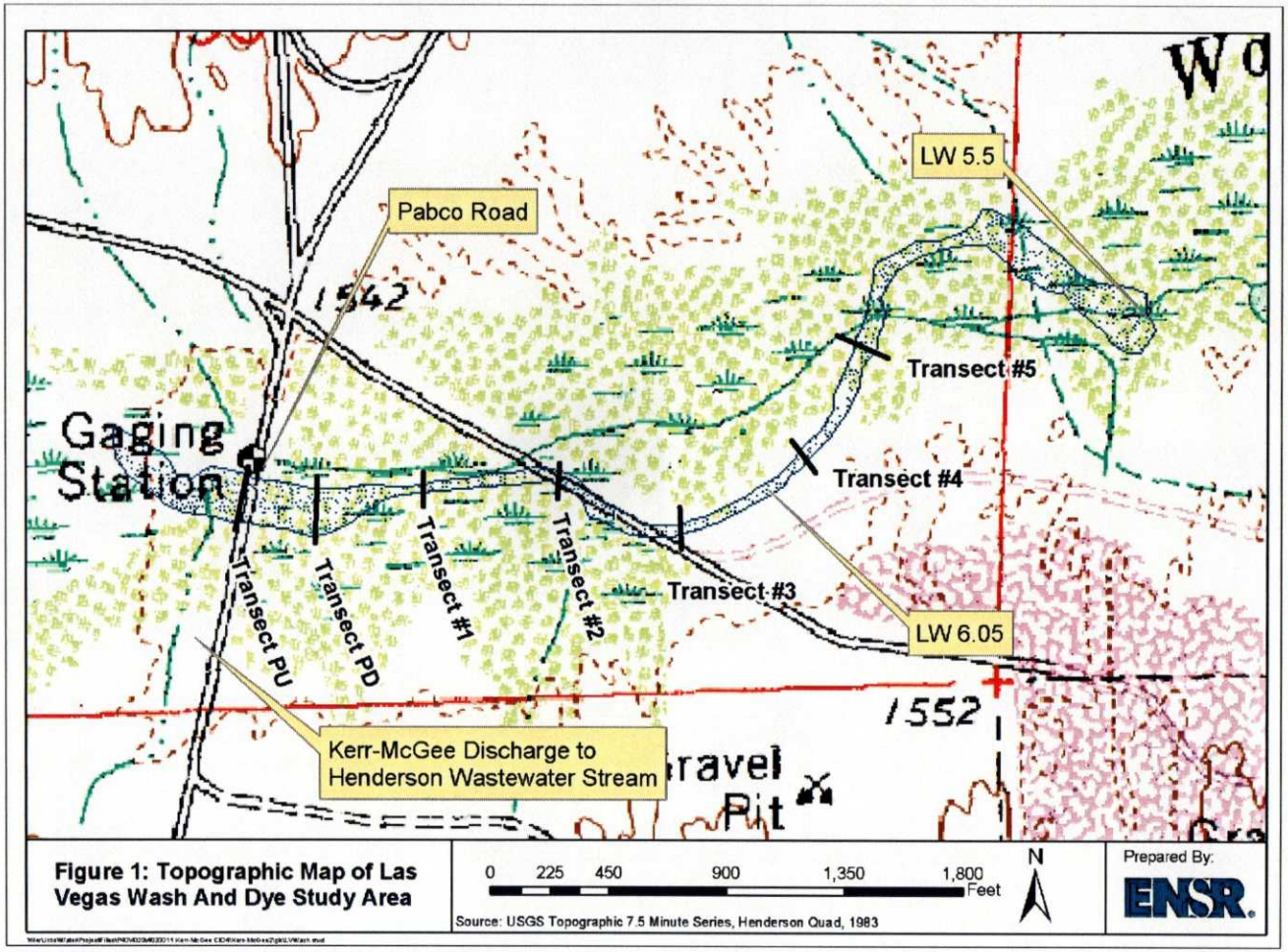


Figure 1: Topographic Map of Las Vegas Wash And Dye Study Area

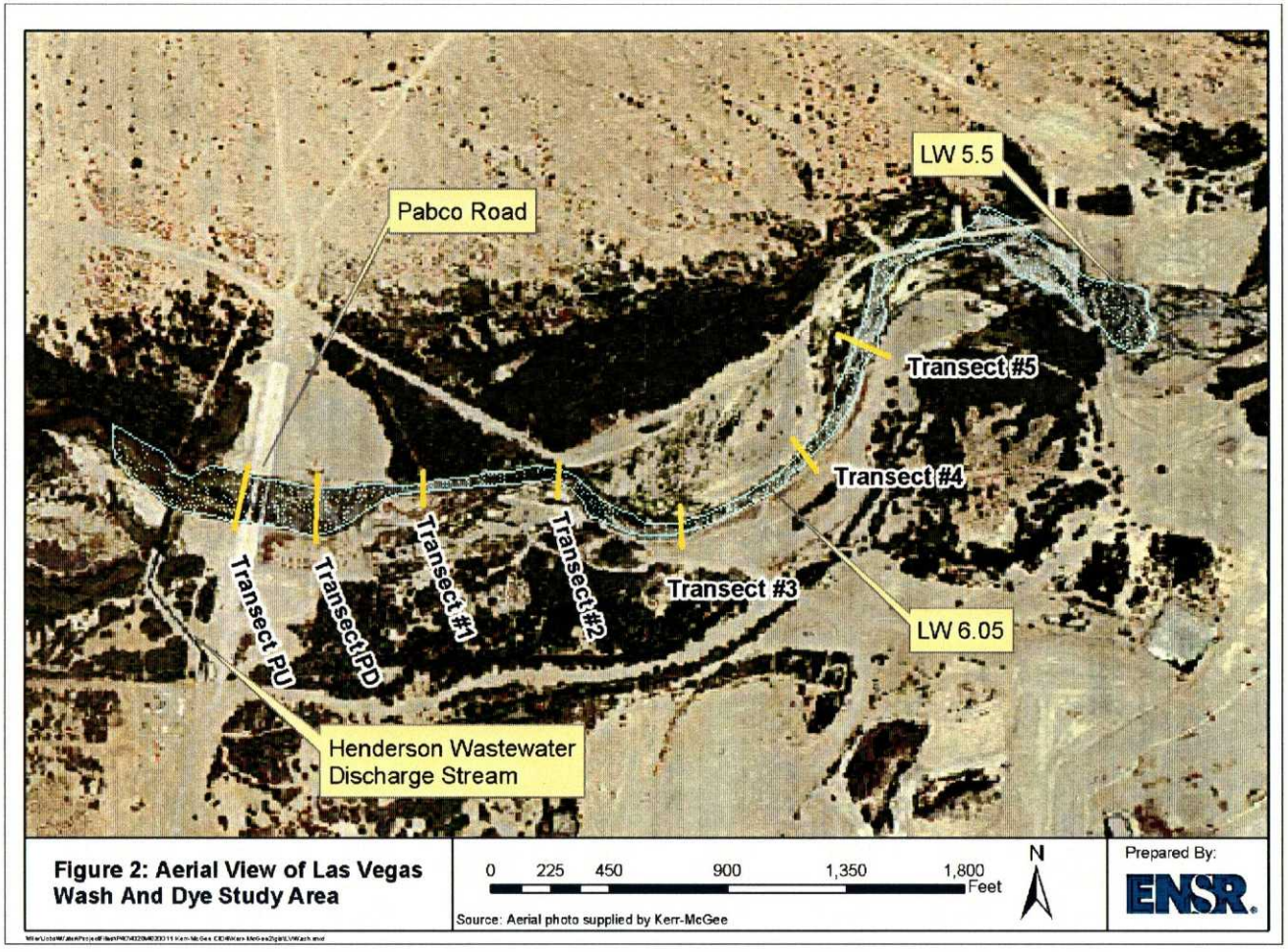


Figure 2: Aerial View of Las Vegas Wash And Dye Study Area

2.0 DESCRIPTION OF LAS VEGAS WASH

2.1 Physical Overview of the Las Vegas Wash

The Las Vegas Wash was formed as a result of the filling of the Las Vegas Valley by sediments that were eroded from the surrounding mountain ranges and from higher elevation areas. The bulk of the sediments that comprise the Las Vegas Wash include easily eroded silts and clays with minor amounts of sand and gravel. The Las Vegas Wash originates in the far northern and western parts of the Las Vegas basin as ephemeral creeks, smaller washes, and runoff channels. The Las Vegas Wash becomes more clearly defined in the southeastern part of Las Vegas Valley where the flow is dominated by discharges from municipal wastewater treatment plants (WWTPs) or publicly owned treatment works (POTWs). From the southeastern part of Las Vegas Valley the Las Vegas Wash continues along an approximately 12-mile course to Las Vegas Bay in Lake Mead.

The morphology of the Las Vegas Wash is generally that of a highly eroded stream channel with steep vertical banks confining a constantly changing meandering stream channel. The channel varies from shallow and wide to narrow and deep and is braided in some locations. The area under investigation during this study extended from the Pabco Road erosion control structure downstream to Station LW 5.5 (Figure 1). The Las Vegas Wash at the Pabco Road erosion control structure (Figure 3) is relatively wide (~200 feet) and shallow (~0.5 feet) while the unrestricted downstream flow near Transect 5 (Figure 4) occupies a narrower channel (~100 feet) that is much deeper (~2 feet). Stream velocities in the Wash downstream of the Pabco Road structures are high (3-5 ft/sec) and correspondingly, the travel time through the study reach is rather short.

Figure 3: Las Vegas Wash at the Pabco Road erosion control structure.

Figure 4: Las Vegas Wash at the most downstream location of the dye study at Transect 5.

2.2 Hydrologic Overview of the Las Vegas Wash

Flows in the Las Vegas Wash originate from tributary flows and treated wastewater discharges, precipitation runoff, and intercepted shallow groundwater. Flows in the Las Vegas Wash have been measured by the USGS since 1957 and are published annually on a water year basis. Since 1957 the USGS has maintained a total of four separate gages on the Las Vegas Wash. One of these gages (#09419700) is located at Pabco Road (Figure 1), just downstream of the Kerr-McGee discharge. Wastewater discharge flow to the Las Vegas Wash originates from the Clark County Sanitation District, the City of Las Vegas, and the City of Henderson municipal wastewater treatment plants. The combined NPDES permitted discharge from the three municipal wastewater treatment plants in the Valley for 1999 is 174 million gallons per day (mgd). Also, a nearby industrial facility, Basic Management, Incorporated (BMI) is permitted to discharge 10 mgd. These sources total 184 mgd (285 cfs); however, actual discharge flow rates are generally lower.

The City of Las Vegas and Clark County discharge to the Las Vegas Wash a considerable distance upstream of the upstream boundary of the study area at Pabco Road. The City of Henderson and BMI discharge into a small channel that enters the Las Vegas Wash upstream of Pabco Road (Figure 1). The discharge from the City of Henderson and BMI enter the Las Vegas Wash by first passing through a small rock-lined channel as shown in Figure 5. This channel is approximately 735 feet long and discharges to the Las Vegas Wash approximately 160 feet upstream of the Pabco Road structure. The Kerr-McGee effluent enters this channel approximately 300 feet upstream of its discharge to the Las Vegas Wash (435 feet downstream of Figure 5).

Figure 5: Henderson discharge channel showing the three main discharge streams upstream of the Kerr-McGee discharge water inflow point; the primary and secondary Henderson wastewater discharges (left and middle) and the BMI discharge (right).

Daily dry weather flows in the Las Vegas Wash consist primarily of municipal wastewater and vary with changes in discharge from the three municipal wastewater treatment plants. The average annual flow measured at the USGS gage at Pabco Road (#09419700) during the year prior to this investigation was 262 cfs. A summary of the monthly average flows measured at the Pabco Road gage indicate that flows are slightly lower during the summer months and can be high during the winter but do not generally vary much throughout the year (Figure 6). Additionally, daily variations in flow can be as much as 100 cfs as indicated in a recent hydrograph from the USGS gage (Figure 7).

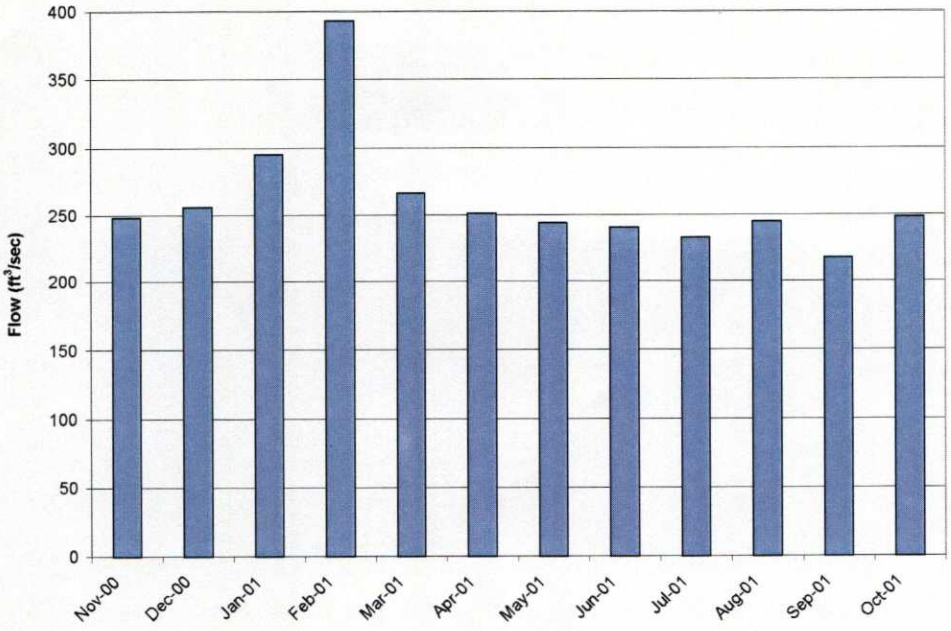


Figure 6: Monthly Average Flow at USGS Gage (#09419700) in the Las Vegas Wash at Pabco Road.

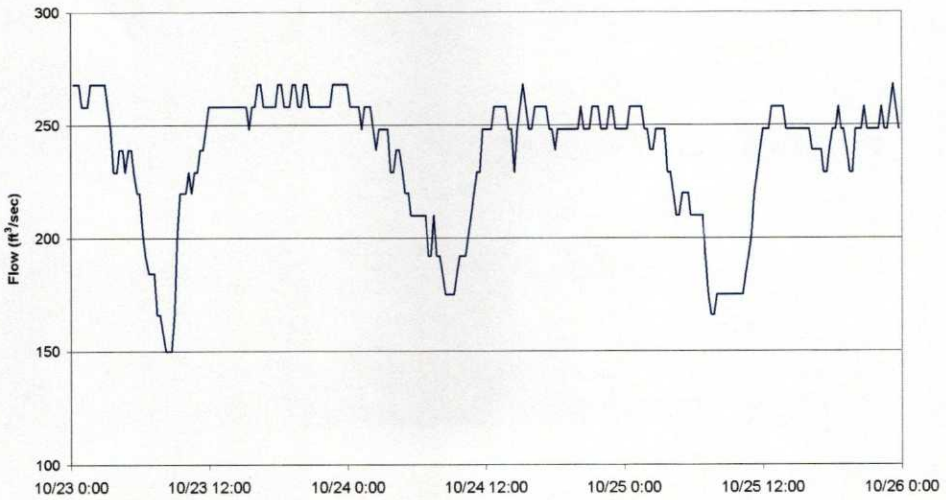


Figure 7: Recent hydrograph from Pabco Road gage (#09419700) on Las Vegas Wash.

Daily variation in flow rate in the Las Vegas Wash is a direct result of the variable discharge rates associated with each of the three POTWs discharging into the Las Vegas Wash. These circumstances could not be avoided during the dye study and resulted in only a quasi-steady state plume during the investigation. The potential change in mixing length due to flow variability was avoided by conducting the dye study during the time period when the average daily flows were reasonably steady (from noon to dusk on October 24).

Flood control structures have been built within the Las Vegas Wash to reduce channel down cutting during episodic high flow events. Erosion is controlled by increasing the channel width with the use of erosion control structures (low head dams) located along the length of the watercourse. In addition to widening the flow in the channel, the erosion control structures pool water upstream. The Pabco Road erosion control structure (Figure 8) located a short distance downstream of the Kerr-McGee discharge insured the vertical mixing of the discharge plume in the Las Vegas Wash.

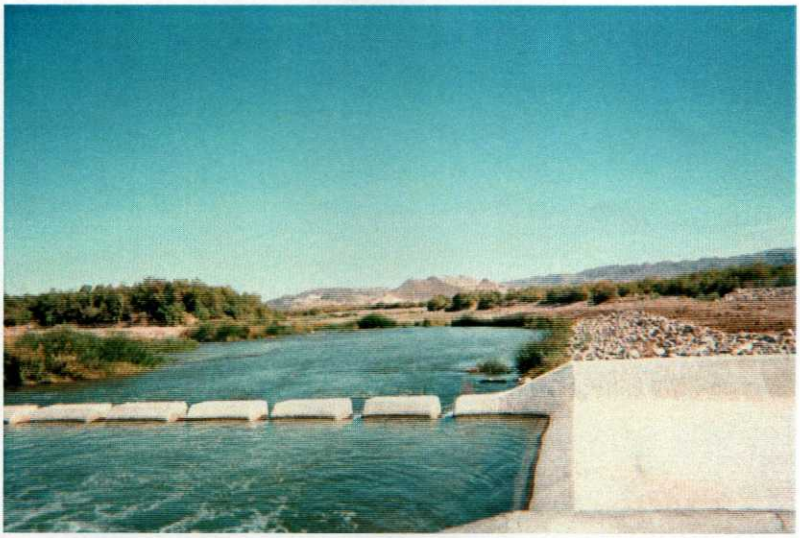


Figure 8: Pabco Road erosion control structure looking downstream.

3.0 FIELD PROGRAM DESIGN & METHODOLOGY

This program involved the injection of Rhodamine WT fluorescent dye into the Kerr-McGee discharge and the measurement of fluorescence at a series of 7 transects downstream of the dye injection (Figure 1, Figure 2). Components of the field procedures are described below.

3.1 Dye Injection

Rhodamine WT dye was injected into the Kerr-McGee discharge at the point where it enters the Henderson discharge channel (Figure 9), approximately 300 feet upstream of the discharge of the channel to the Las Vegas Wash. The discharge enters the channel from the vegetated area on the opposite side of the dirt road in the photo (Figure 9). The discharge traverses the road and travels through the rip-rip opposite the dye injection setup. Dye was injected here rather than at the point of the Kerr-McGee discharge in the seep. Injecting dye into the rip-rap channel rather than directly into Kerr-McGee's initial discharge was considered to be equivalent for this study since, in either case, the dye would be completely mixed in the Henderson discharge channel on entering the Las Vegas Wash.

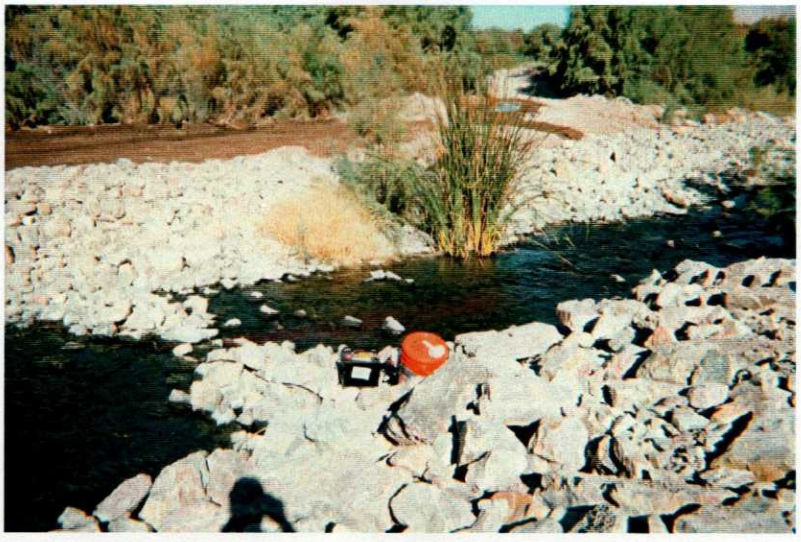


Figure 9: Dye injection pump (center of photo) located opposite of where the Kerr-McGee discharge enters into the Henderson wastewater discharge channel.

The Rhodamine WT dye was diluted to 50% with water and then injected into the Henderson Discharge channel. Dye was injected using a FMI fluid injection pump[2] at a pumping rate of approximately 10 ml/min. At this rate, it was calculated that the instream dye concentration would be 40 ppb assuming a flow rate of 300 cfs. The pump, accurate to 1% at the 10 ml/min injection rate, was calibrated at the start and end of the dye test, using a graduated cylinder to insure that the injection rate remained constant.

To obtain a quasi-steady state dye concentration in the Las Vegas Wash, the dye was injected for a period of four hours before collection of samples for fluorescence measurement at downstream transects. Overall, the dye was injected for a period of approximately seven hours, from 10:00 a.m. to 5:00 p.m. (Figure 10).

[2] ENSR, 2000. Work Plan for a Dye Injection Study of the Las Vegas Wash, Nevada. Prepared for Kerr-McGee Chemical Corporation, L.L.C. Document No. 4020-011-100.

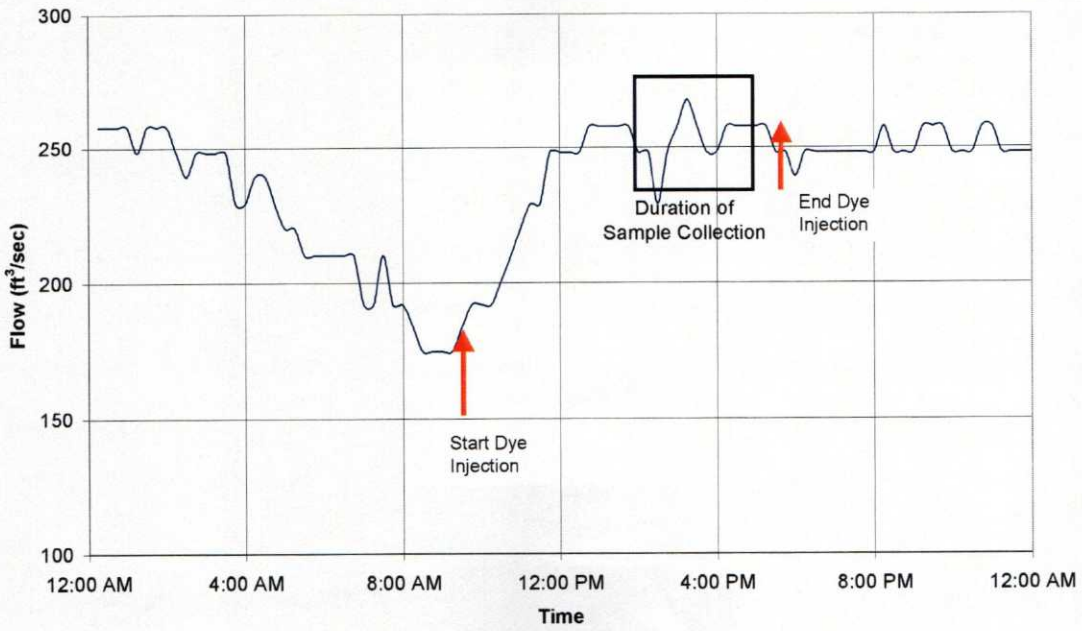


Figure 10: Hydrograph at the USGS gage (#09149700) Pabco Road indicating dye injection including a window representing the time period when transect samples were collected.

3.2 Selection of Transects

Transects were chosen along the Las Vegas Wash to determine where Kerr-McGee's discharge was completely mixed in the Las Vegas Wash. The most upstream transect, Pabco Road Upstream (PU) (Figure 1) was located at the upstream side of the Pabco Road crossing, approximately 160 feet downstream of where the flow from the Henderson discharge channel enters the Las Vegas Wash. This was selected as the most upstream transect since the dye was expected to have minimally mixed in the Las Vegas Wash at this point. The most downstream transect was located approximately 3,000 feet downstream of Pabco Road at station LW5.5 (Transect 5). Based on previous calculations of mixing length[3] and the current physical characteristics of the Las Vegas Wash, it was assumed *a priori* that the dye would be completely mixed across the channel at this location (Figure 1, Figure 2). Therefore, all additional transects were located upstream of LW5.5, and were distributed to illustrate the pattern of mixing in the Las Vegas Wash.

[3] Kerr-McGee LLC. Letter from Susan Crowley to the Nevada DEP. April 13, 2000.

3.3 Collection of Water Samples

Based on the estimated average daily high flows of approximately 300 cfs, and measured velocities of 3-5 ft/sec, the dye was assumed to reach a quasi-steady state in the Las Vegas Wash (to 3000 feet downstream) within approximately one hour after the commencement of dye injection. Water sampling began after four hours of dye injection (Figure 10). Five discrete water samples were taken at each transect in order to measure the fluorescence variability across the stream. Grab water samples were collected laterally and at mid-depth in an evenly distributed fashion (Figure 11), where sample C was the mid-point between samples A and E, and samples B and D were half-way between the adjacent samples. In addition, one water sample was taken where the rock-lined channel discharges into the Las Vegas Wash. Samples were collected by wading to the appropriate location and submerging the sample bottles by hand, or at the end of a 6' wooden pole, until the bottle was full. These water samples were kept in the dark and measured within 24 hours for fluorescence using a Turner fluorometer[4], which was factory calibrated to show readings in parts-per-billion or ppb.

3.4 Streamflow Measurements

Streamflow measurements were made during the dye study with a Marsh-McBirney Model 2000 electromagnetic current meter. Stream velocity measurements were made at approximately mid-depth at a minimum of 20 locations across each channel transect using the current meter. Flow measurements were made in accordance with the procedure outlined in the project workplan[3]. Streamflow was measured at the Pabco Road transect (Transect PU) and at the furthest downstream transect (Transect 5) during the time period of average daily high flows in the Las Vegas Wash. Streamflow was measured at the Pabco Road structure for comparison with the USGS instantaneous flow measured at the Pabco gage; streamflow was measured at the downstream transect for comparison with the upstream flow measurement, and thus indicate whether there was any loss or gain in volume of water.

[4] ENSR, 2000. Work Plan for a Dye Injection Study of the Las Vegas Wash, Nevada. Prepared for Kerr-McGee Chemical Corporation, L.L.C. Document No. 4020-011-100.

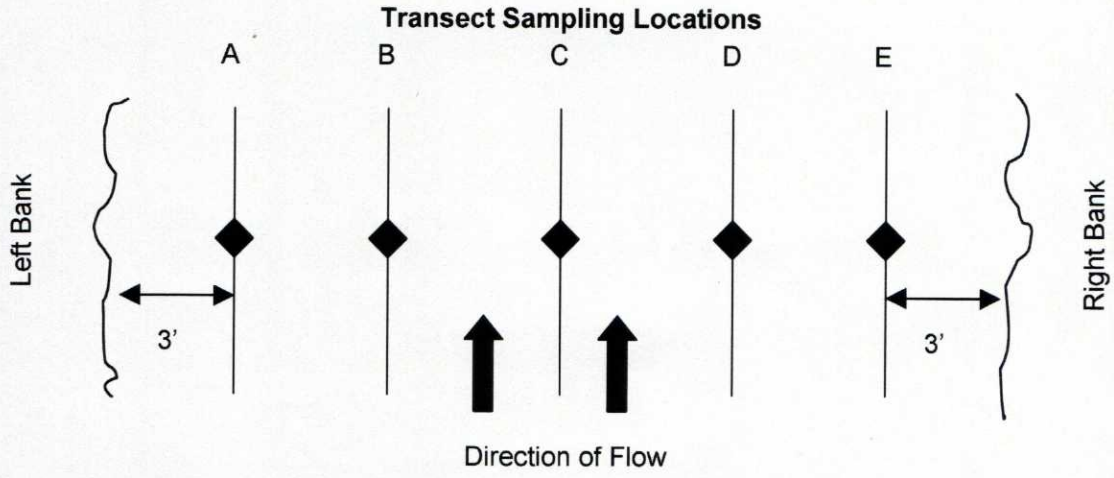


Figure 11: Illustration of lateral fluorescence sample locations at each transect.

4.0 RESULTS

4.1 General Observations

The dye was clearly visible in the Henderson wastewater discharge channel and was visible to a lesser extent in the Las Vegas Wash to the immediate downstream side of the Pabco Road erosion control structure. However, the dye was not visible in the Las Vegas Wash more than approximately 100 feet downstream of the Pabco Road structure.

4.2 Dye Concentration Measurements

Table 1 summarizes the measured dye concentrations for the samples collected in this study, including: a background sample; a sample collected from within Henderson discharge channel downstream of the dye injection point; and samples collected at all seven transects. The background sample, which was collected in the Las Vegas Wash upstream of the Henderson discharge, had an equivalent dye concentration of 0.91 ppb. Since there are other compounds with the potential to fluoresce (and be picked up by the fluorometer), this background concentration was not unexpected. The dye concentration measurement in the Henderson discharge channel (330 ppb) represents the dye concentration entering the Las Vegas Wash for this study.

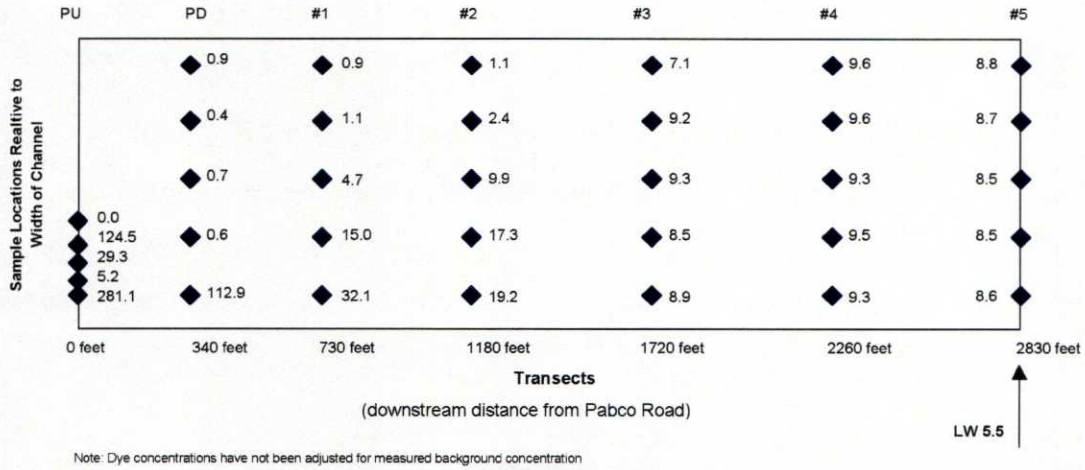
The dye concentrations measured at the seven transects is also illustrated in Figure 12. This figure indicates that the dye initially remains confined to the south side (right side looking downstream) of the Las Vegas Wash at Transects PU, PD, #1 and #2. The dye concentrations at Transects #3 and #4 indicate a transition from incomplete to complete lateral mixing of the Kerr-McGee discharge in the Las Vegas Wash. The dye concentrations at Transects #4 and #5 indicate complete mixing across the channel. Therefore, the dye was completely mixed laterally across the channel at approximately 2,830 feet downstream of the Pabco Road crossing (approximately 3,000 feet downstream of the Henderson discharge channel). A few of the dye measurements were less than that of the background sample; however, this difference indicates a minor variability in the background characteristics, and was not believed to be of significance for this study.

Table 1: Dye Concentrations and locations.

Transect	Station ID	Dye Concentration (ppb)	Distance from Pabco Road (ft)	Sample Distance from Left Bank (ft)
	Background	0.91	0	N/A
	Disch. Chan.	329.79	-160	N/A
PU	PUa	0.00	0	146
	PUb	124.47	0	176
	PUc	29.29	0	181
	PUd	5.22	0	186
	PUe	281.07	0	193
PD	PDa	0.87	340	3
	PDb	0.35	340	52
	PDc	0.70	340	100
	PDd	0.58	340	149
	PDe	112.87	340	197
1	1a	0.87	730	3
	1b	1.10	730	15
	1c	4.70	730	27
	1d	15.02	730	38
	1e	32.08	730	50
2	2a	1.10	1180	3
	2b	2.38	1180	18
	2c	9.86	1180	34
	2d	17.29	1180	49
	2e	19.20	1180	64
3	3a	7.14	1720	3
	3b	9.17	1720	10
	3c	9.34	1720	17
	3d	8.47	1720	24
	3e	8.93	1720	31
4	4a	9.57	2260	3
	4b	9.57	2260	12
	4c	9.34	2260	20
	4d	9.51	2260	29
	4e	9.34	2260	37
5	5a	8.76	2830	3
	5b	8.70	2830	22
	5c	8.47	2830	44
	5d	8.47	2830	65
	5e	8.59	2830	90

* Note: Listed concentrations have not been adjusted for measured background concentration

Figure 12: Diagram of measured dye concentrations at each transect.



Note: Dye concentrations have not been adjusted for measured background concentration

4.3 Streamflow

Streamflow was measured at the Pabco Road structure for comparison with the USGS flow measured at that site; this measurement was made to verify the accuracy of the USGS gage. Streamflow was also measured at the downstream transect. This downstream streamflow measurement was made to indicate whether any additional water was entering the Las Vegas Wash between the upstream and downstream transects. The streamflow measured during the investigation at Pabco Road is shown below in Figure 13 as a red triangle over the hydrograph from the USGS gage (#9419700) at Pabco Road. The ENSR measured streamflow of 220 cfs is 14.7% less than the USGS gage measurement of 258 cfs. Downstream at Transect #5 streamflow was measured at 236 cfs, which is 7.3% more than the flow measured at Pabco Road. In each case, the difference in flow rates is within the range of error associated a single streamflow measurement. Furthermore, on walking the river course from the Henderson discharge channel downstream to Transect #5 there was no evidence of any additional surface water entering the Las Vegas Wash.

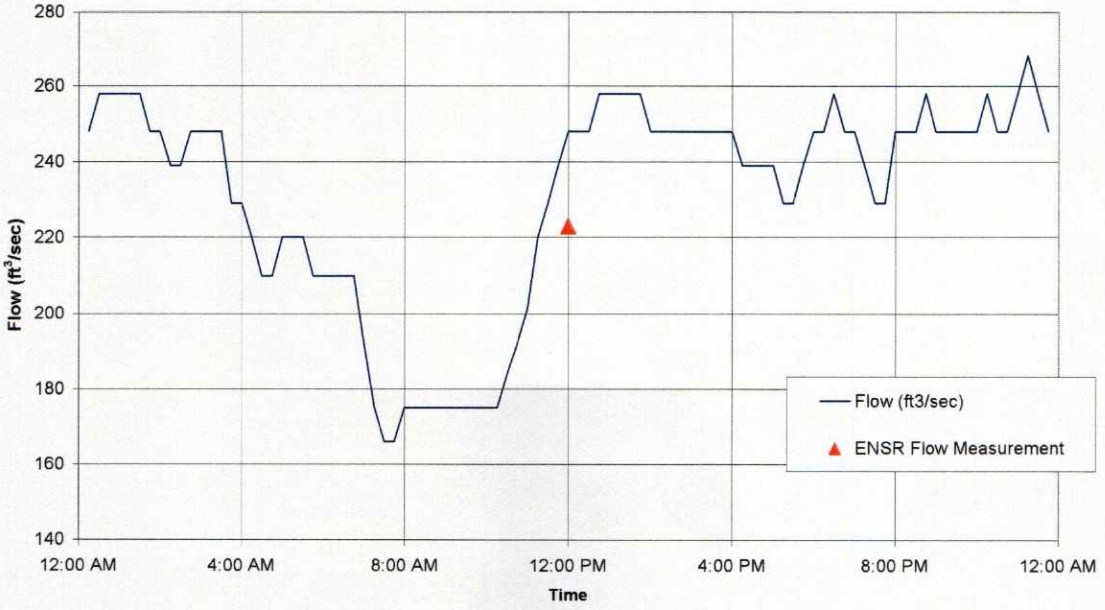


Figure 13: Comparison of ENSR Flow with USGS Flow at Pabco Road gage.

5.0 CONCLUSIONS

This study focused on mixing characteristics in the Kerr-McGee perchlorate treatment system discharge in the Las Vegas Wash. Specifically, ENSR conducted a dye study to measure the mixing of the discharge plume in the Las Vegas Wash. Fluorescent dye was injected in the discharge channel (Figure 1, Figure 2) at a rate to insure a concentration above the natural background fluorescence. Water samples were taken at seven transects located downstream of the Kerr-McGee discharge in the Las Vegas Wash and subsequently measured for dye equivalent concentration.

Results of this dye study show that the discharge enters the Las Vegas Wash and remains unmixed and localized to the right bank of the channel until it flows past the Pabco Road structure (Figures 3, Figure 9). Upon flowing through the Pabco Road structure, the plume partially disperses laterally. Complete lateral mixing of the plume occurs 2,400 feet downstream. Therefore the discharge fully mixes in with the waters of the Las Vegas Wash prior to LW 5.5, which is approximately 3,000 feet downstream of the Henderson discharge (Figure 1, Figure 2). Flows in the Las Vegas Wash as measured by the USGS and ENSR at the time of this study indicate that the dye injection study was conducted during a typical daily average flow rate. Furthermore, the difference between the upstream and downstream flow measurements of 220 cfs and 236 cfs, respectively may be the result of groundwater seepage between the two transects along the Las Vegas Wash; however, this difference is within the expected error associated with a single instream flow measurement.